

TRMM Microwave Imager Microwave Brightness Temperature Legacy Product version-8

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TRMM Microwave Imager (TMI) Legacy Brightness Temperature Product version-8

- The entire > 17-year TMI time series has been reprocessed to produce the V8 Tb product
- To improve the quality of this legacy product, major revisions of the former 1B11 “Rad_counts-to-Tb” processing software were implemented
- This paper briefly summarizes this significant XCAL accomplishment

History of TMI 1B11

- During on-orbit start-up, TMI measurements of the oceans were discovered to be too warm
 - A “deep space calibration” maneuver was performed and the TMI reflector was found to be slightly emissive (~3%); therefore

$$T_{ant} = (1 - \epsilon) * T_{earth_{scene}} + (\epsilon) * T_{phy}$$

History of TMI 1B11

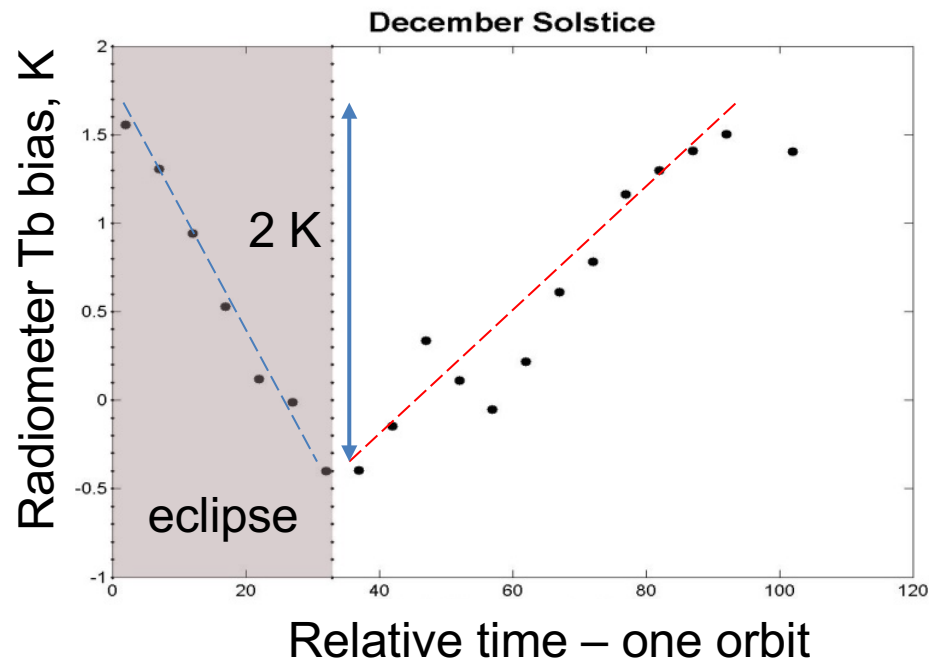
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- During the TRMM Cal/Val period, the orbit mean bias was removed by inter-calibration with SSM/I
- This became **1B11 Version-6**

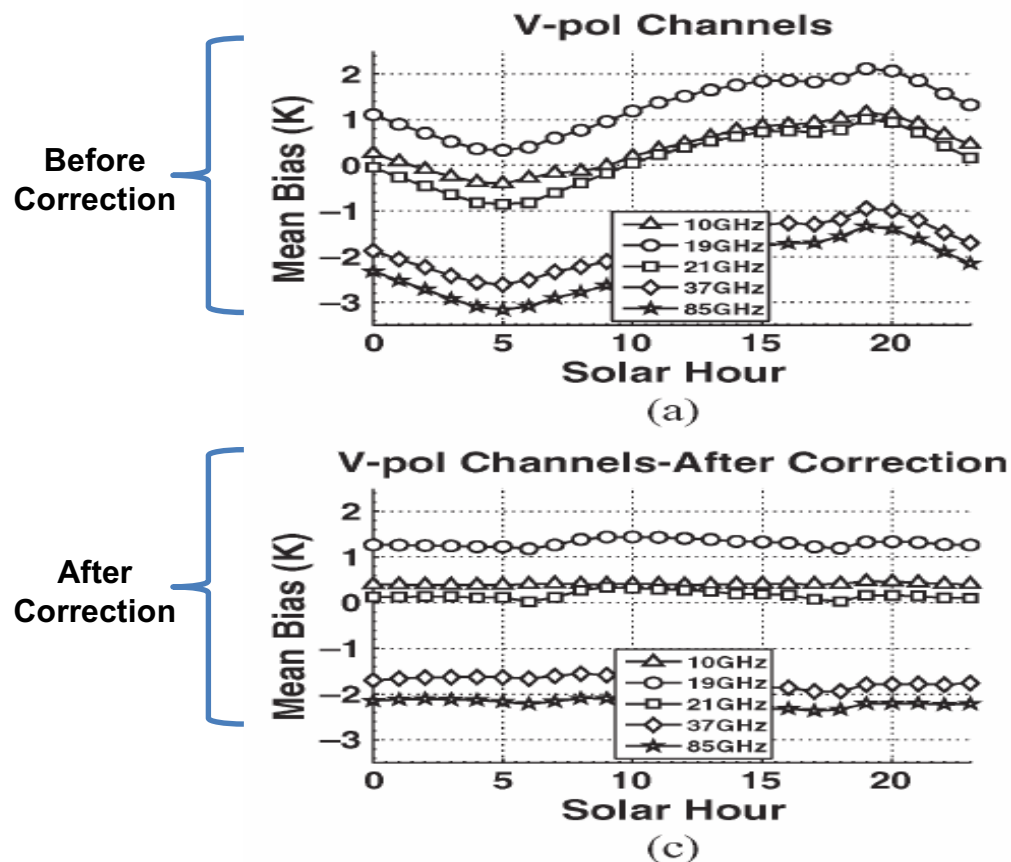
History of TMI 1B11 cont.

- Unfortunately, the reflector T_{phy} varied over the orbit and it was not measured, which produced a time-variable Tb error in 1B11 V6, which was ignored



History of TMI 1B11 cont.-2

- In 2004, XCAL was formed and this calibration error was rediscovered during inter-satellite comparisons
 - Based upon Channel 10V, an empirical correction was implemented in **1B11 V7**



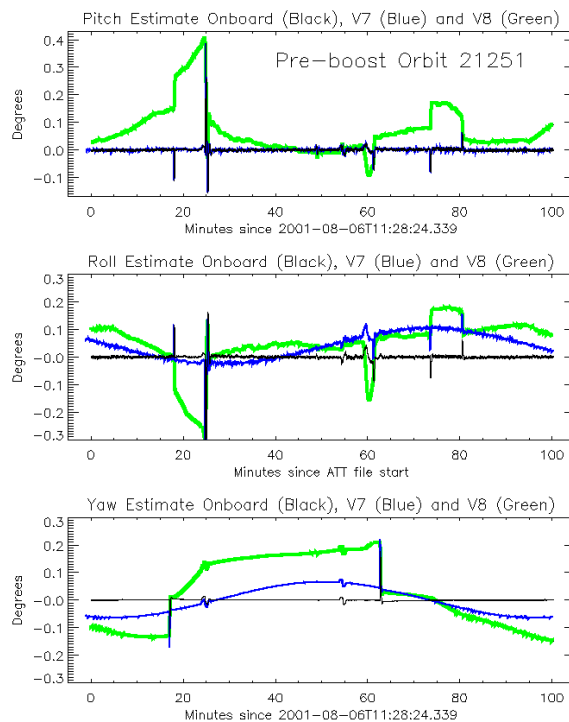
TMI Brightness Temps V8 Objectives

- To replace all previous ad hoc corrections with a new rigorous Rad_counts-to-Tb algorithm based upon on-orbit measurements and EM theory
- The major changes included:
 - Improved spacecraft attitude → TMI Geolocation
 - Cross-track (azimuth scan angle) Tb bias correction
 - TMI emissive reflector correction
 - TMI hot-load correction (new)
 - RFI in cold reflector correction (new)

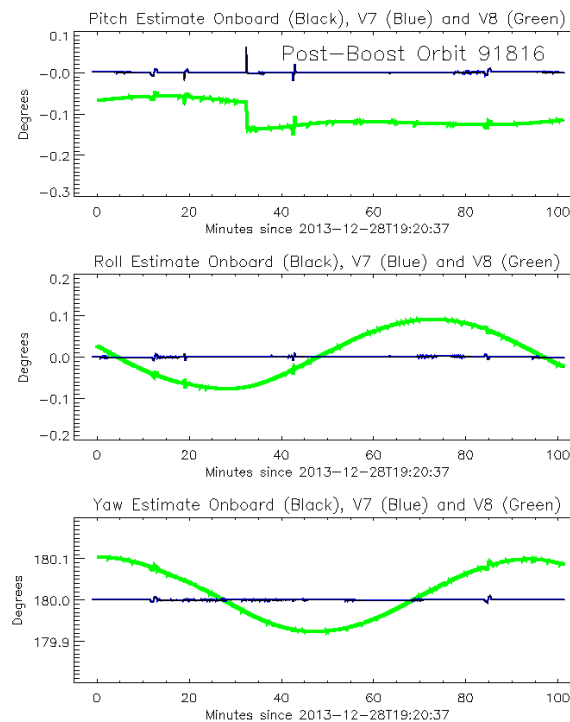
TRMM Spacecraft Attitude History Recalculated using PR roll estimates, Sun-Sensor and Gyro data

Sample Orbits

Preboost: errors up to 0.4° due to Sun effect on Earth Sensor

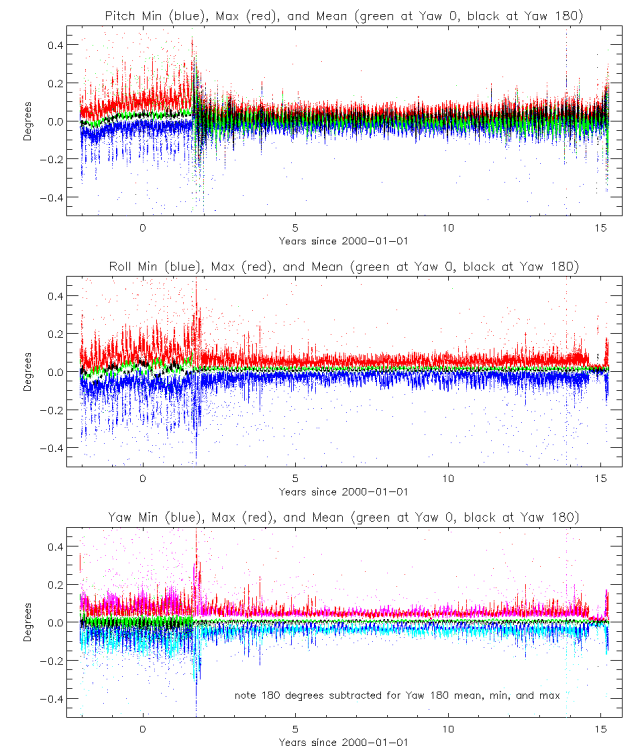


Postboost: errors often $> 0.1^\circ$ with pitch drift and sinusoidal roll/yaw



Trends in Min/Max/Mean

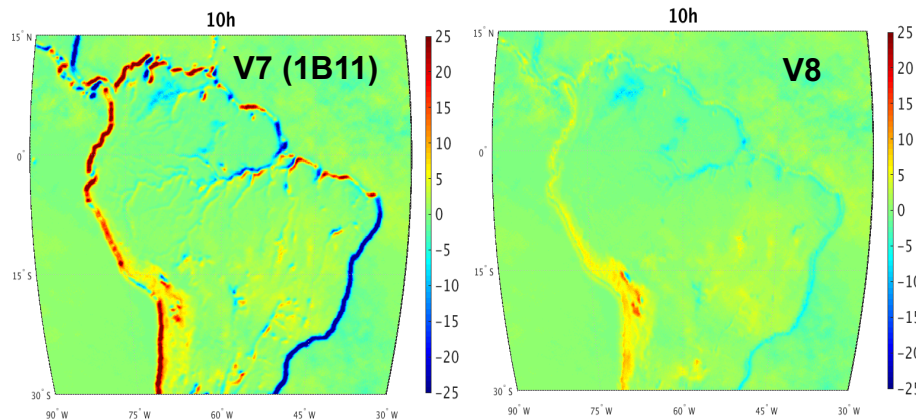
Motion now tracked to $< 0.01^\circ$ showing true attitude variation



TMI Geolocation and Cross-Track Bias Corrections

TMI Pointing Accuracy

- Spin axis alignment (pitch/roll offsets) derived from analysis of cross-track bias patterns
- Feed horn mount offsets (cone angle and azimuth start angle) derived from coastline analysis of yaw-0 versus yaw-180 differences

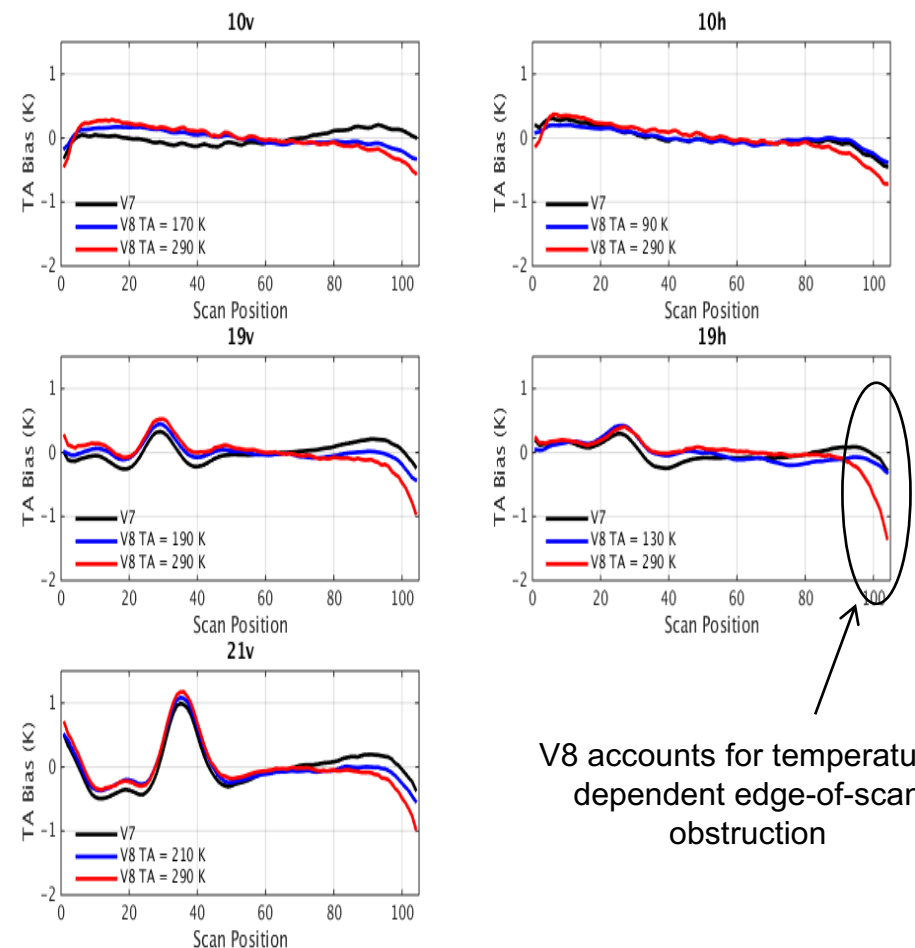


Delta Cone & Azimuth Start Angle Offsets from V7 to V8

Channel	Cone Angle		Cone Angle Offset for EIA	Azimuth Start Angle	
	V7	V8		V7	V8
10 GHz	49.0	49.45	10v: -0.048 10h: +0.048	-64.4024	-63.91
19, 21, 37, 85 GHz	49.0	49.28	0	-64.4024	-64.36

Cross-Track Bias Correction

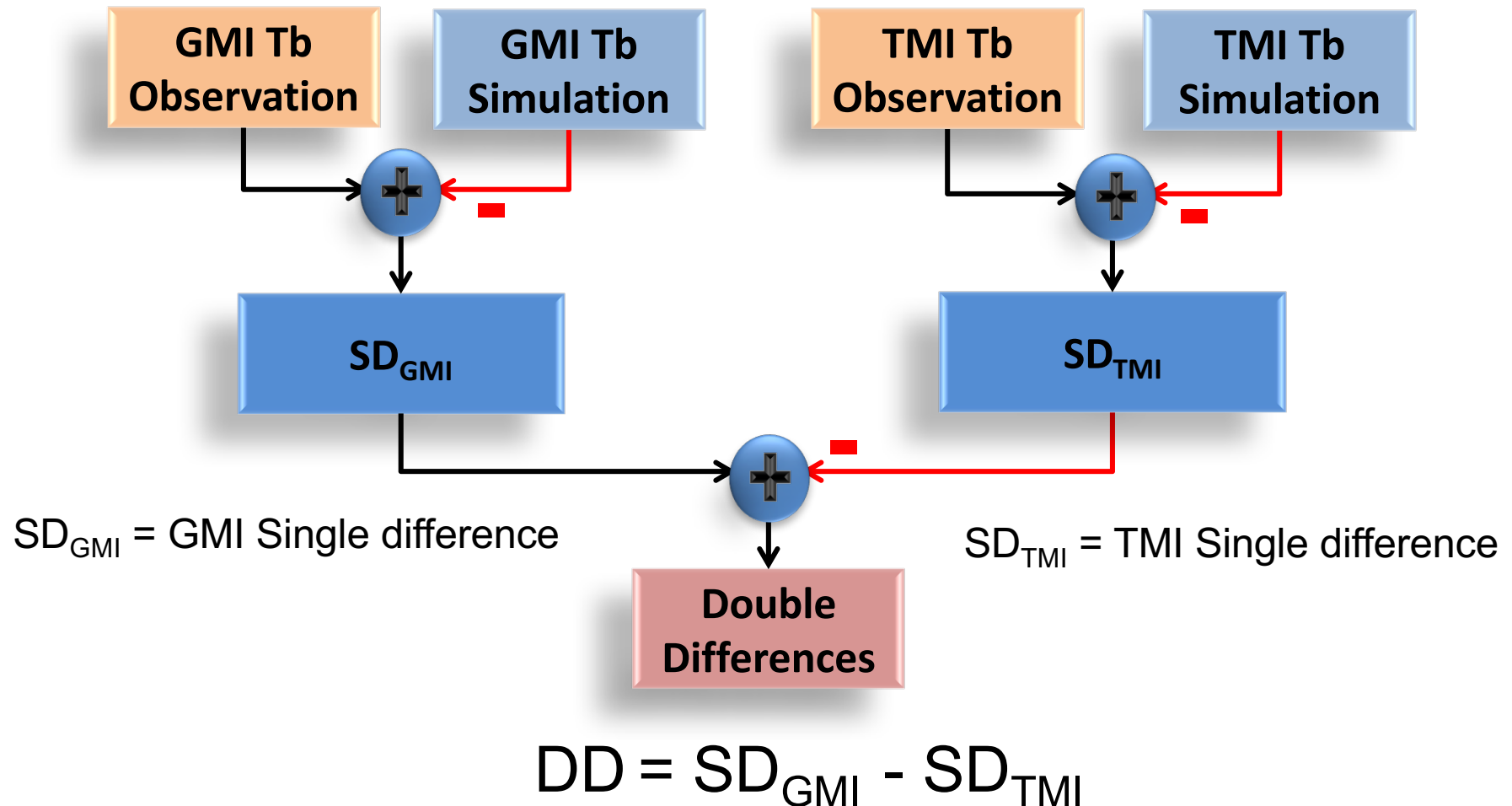
- V8 derived along-scan correction as a function of temperature, using a linear interpolation between vicarious cold and warm techniques



V8 accounts for temperature-dependent edge-of-scan obstruction

XCAL Radiometric Double Differences

GPM provided 13 month overlap with TRMM



Emissive Reflector Correction Procedure

- Measure the reflector emissivity for each TMI channel
 - A special deep space calibration maneuver @ end of TRMM mission
- Calculate Earth scene brightness

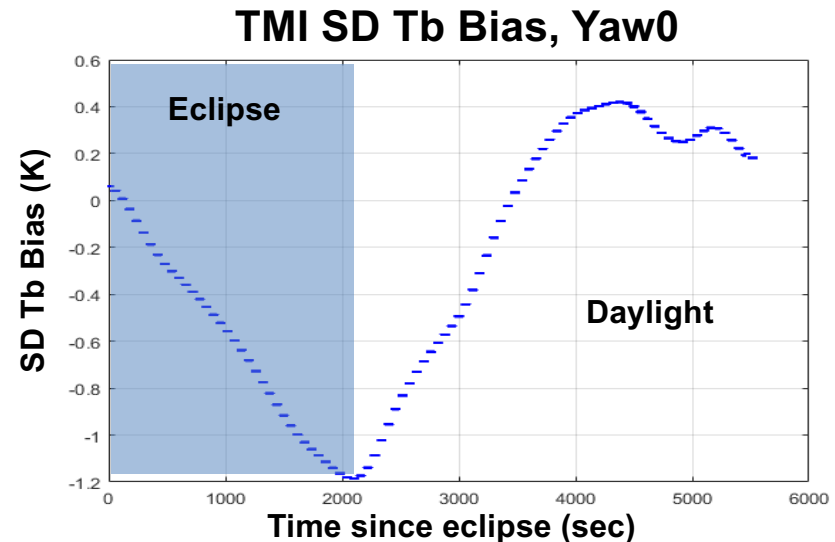
$$T_{earth_scene} = \frac{T_{ant} - \epsilon T_{phy}}{(1 - \epsilon)}$$

Not measured

TMI Reflector Physical Temperature Derivation

- Reflector T_{phy} derived during normal science operations using 10V channel brightness SD_{TMI}

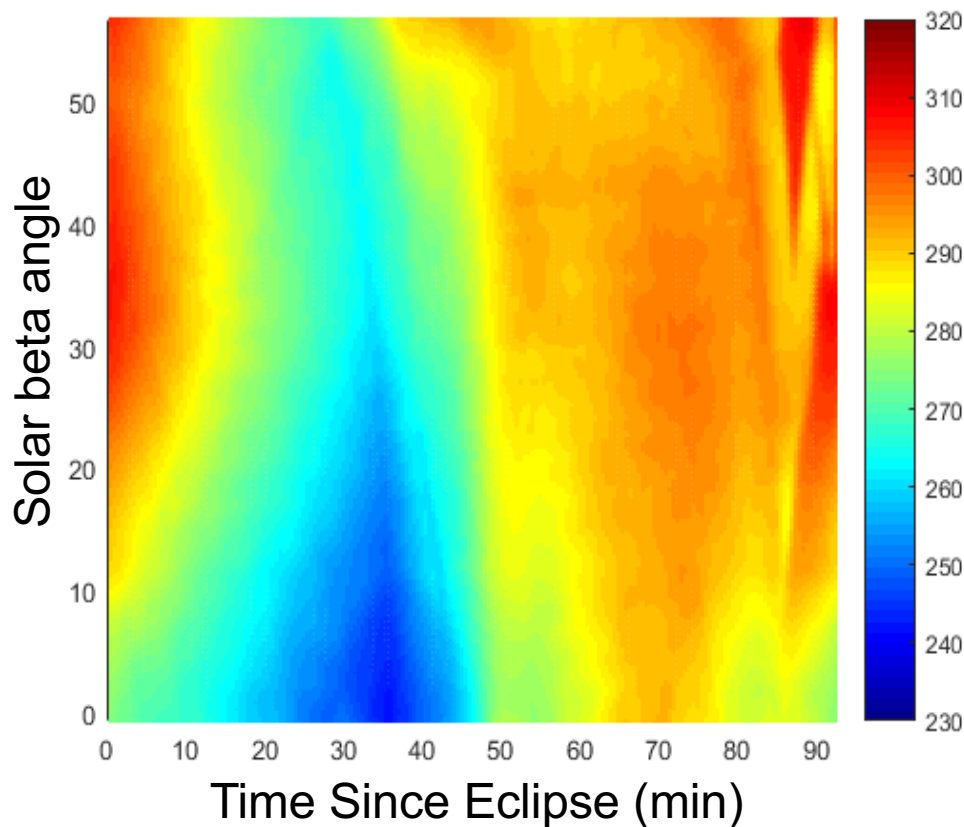
$$T_{phy} = const * SD_{TIM} / (emissivity_{10V})$$



- Data collected for 10-years
 - Separately for yaw0 & yaw180
 - Gridded as a function of solar beta angle (0.25 deg) and time since eclipse (30 sec)

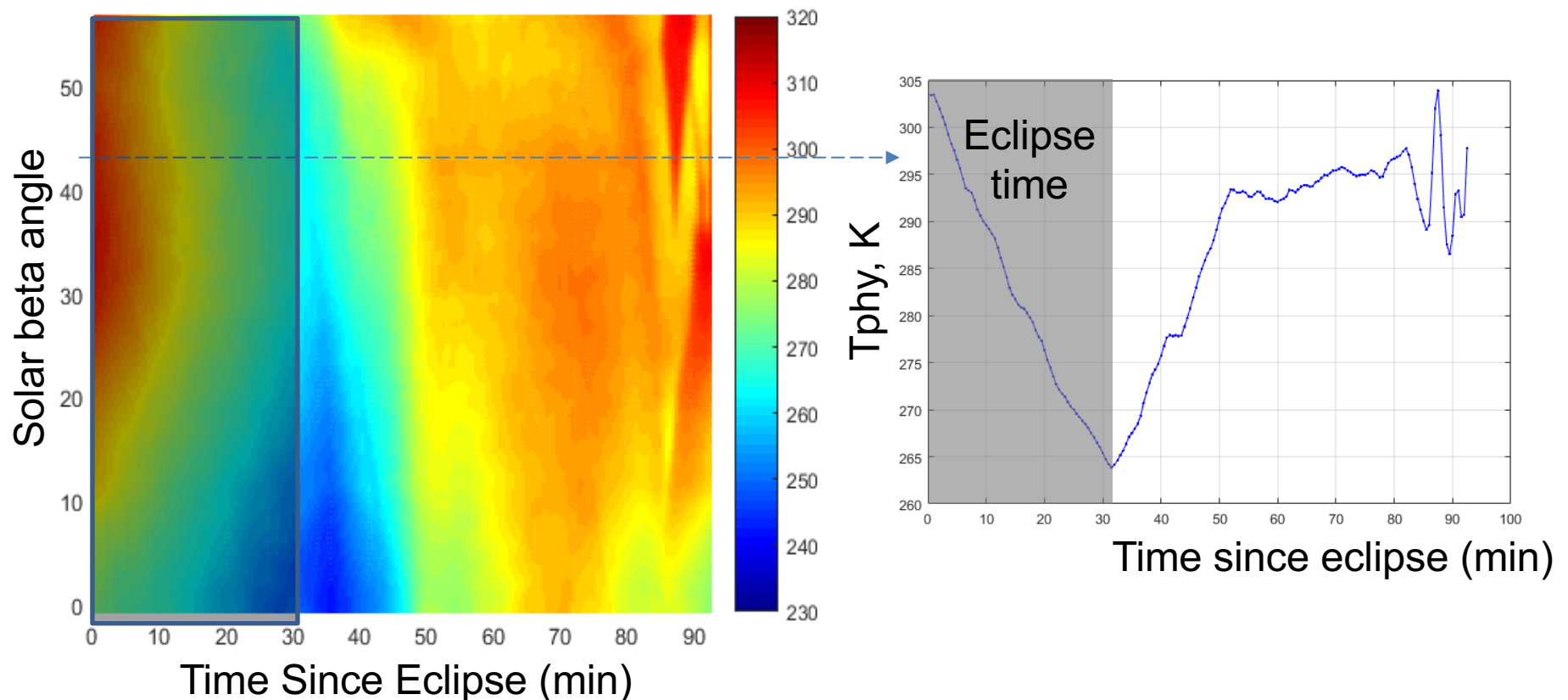
Main Reflector T_{phy} (2003-2013, yaw0)

T_{phy} was derived as a function of solar beta angle and time since entering eclipse



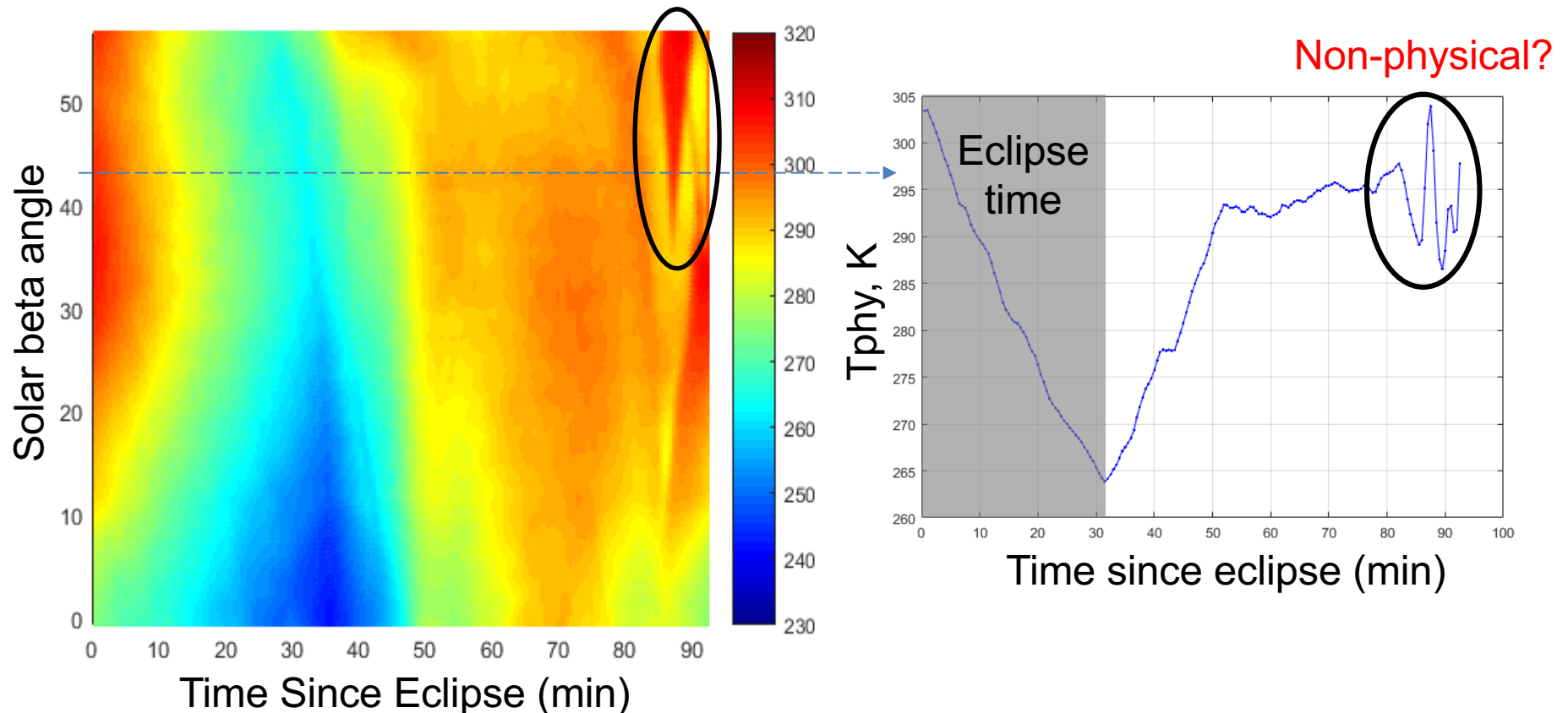
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Main Reflector T_{phy} (2003-2013, yaw0)

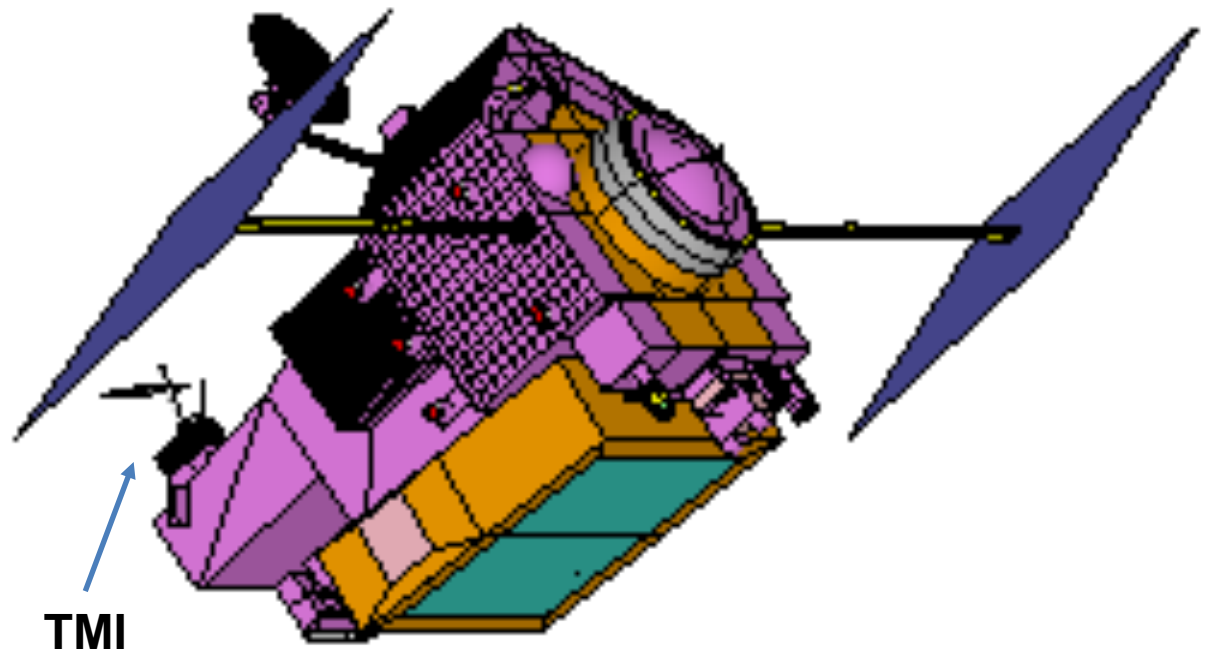
T_{phy} was derived as a function of solar beta angle and time since entering eclipse



Geometry of Solar Intrusion on TMI Hot Load



**TMI Instrument
showing hot load at
center.**

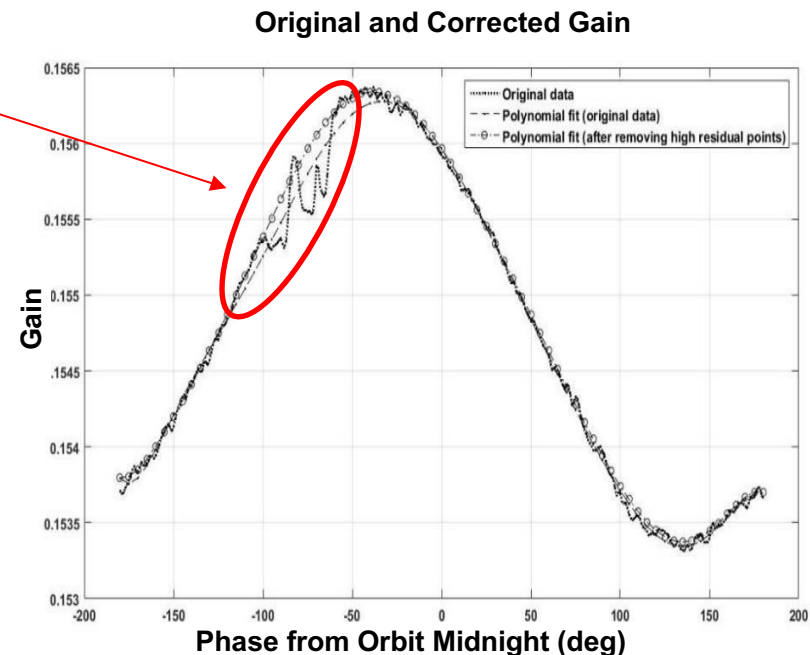


**Spacecraft as seen from Sun at high solar
beta angle before Earth shadow entry.**

TMI Hot-Load Correction

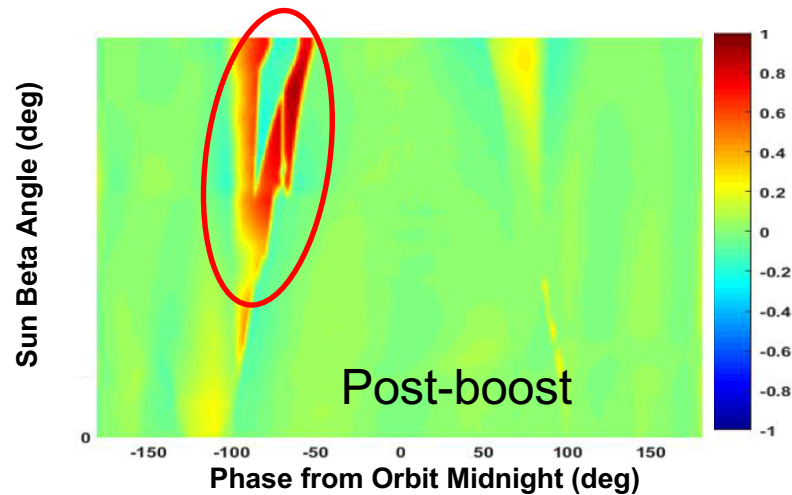
At high solar beta angle, solar intrusions onto TMI hot-load occurred, which resulted in an anomalous gain calculation

To remove this error, we introduced correction of the hot load temp (ΔT_h), which was added to the hot load physical temp measurement

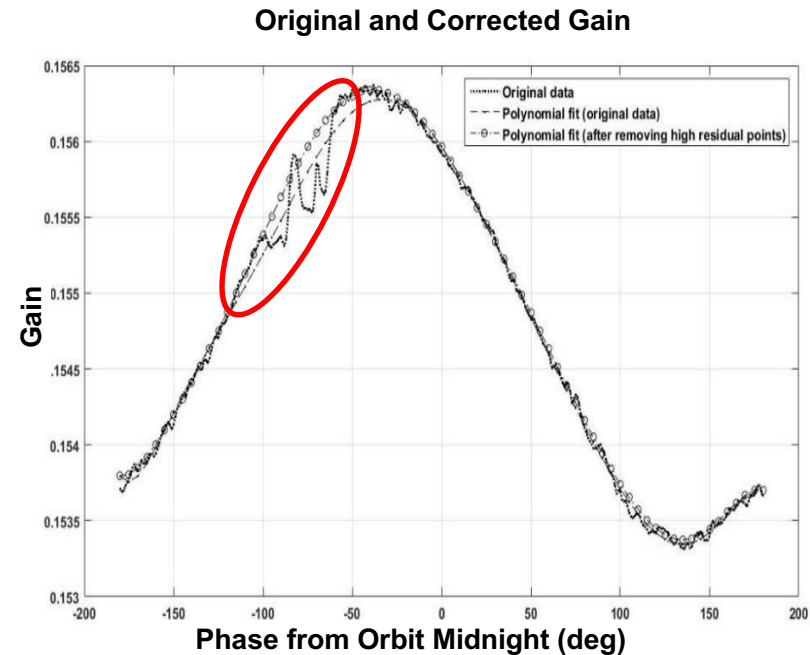


TMI Hot-Load Correction

Correction for solar intrusions into TMI hot-load implemented for V8 were applied as function of the Solar Beta Angle and Phase from Orbit Midnight (related to time since eclipse)

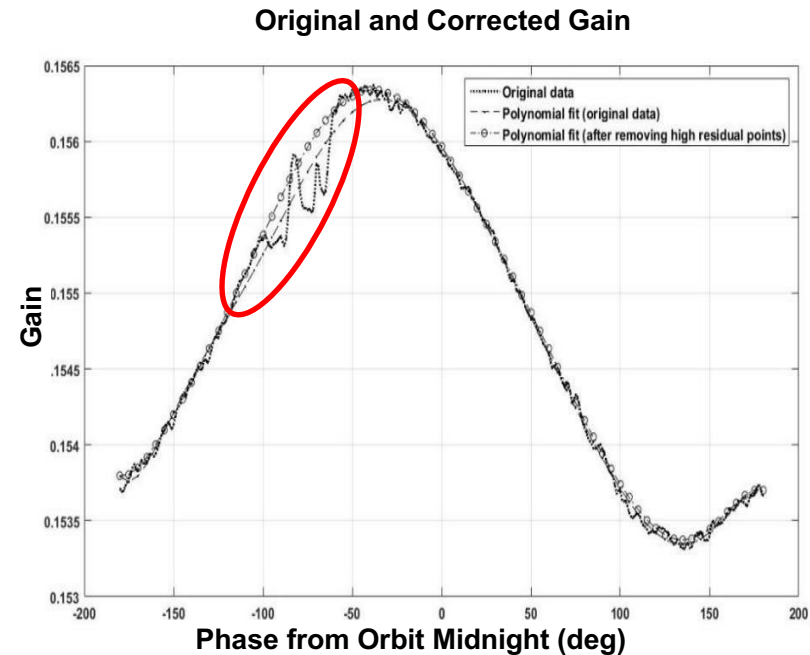
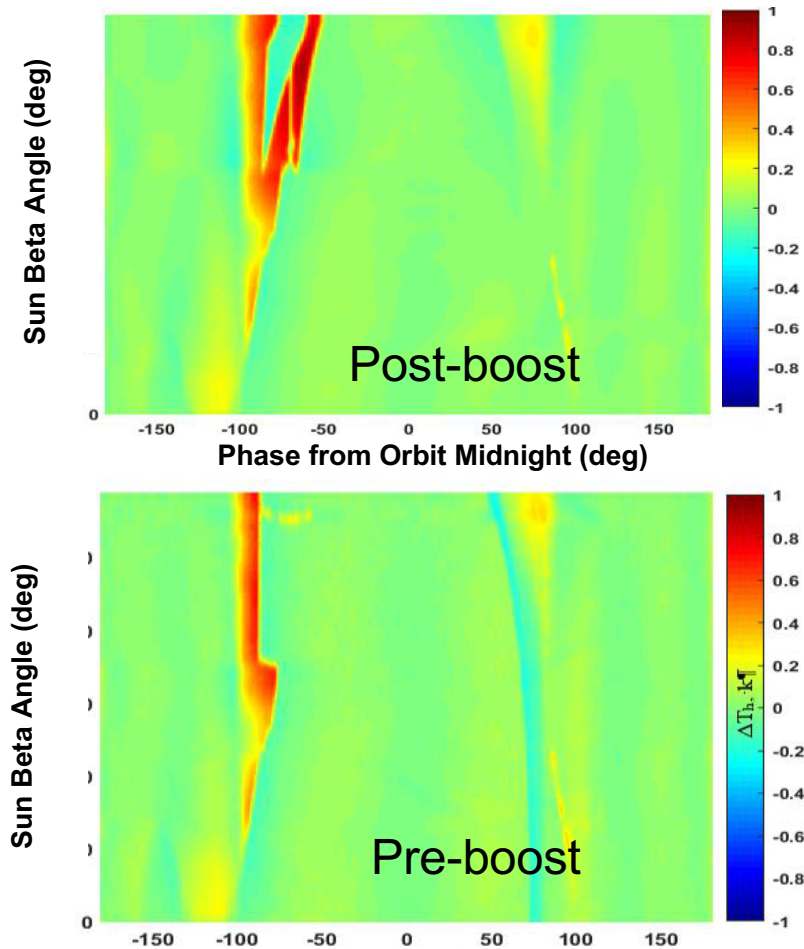


hot load temperature Correction
(ΔT_h)



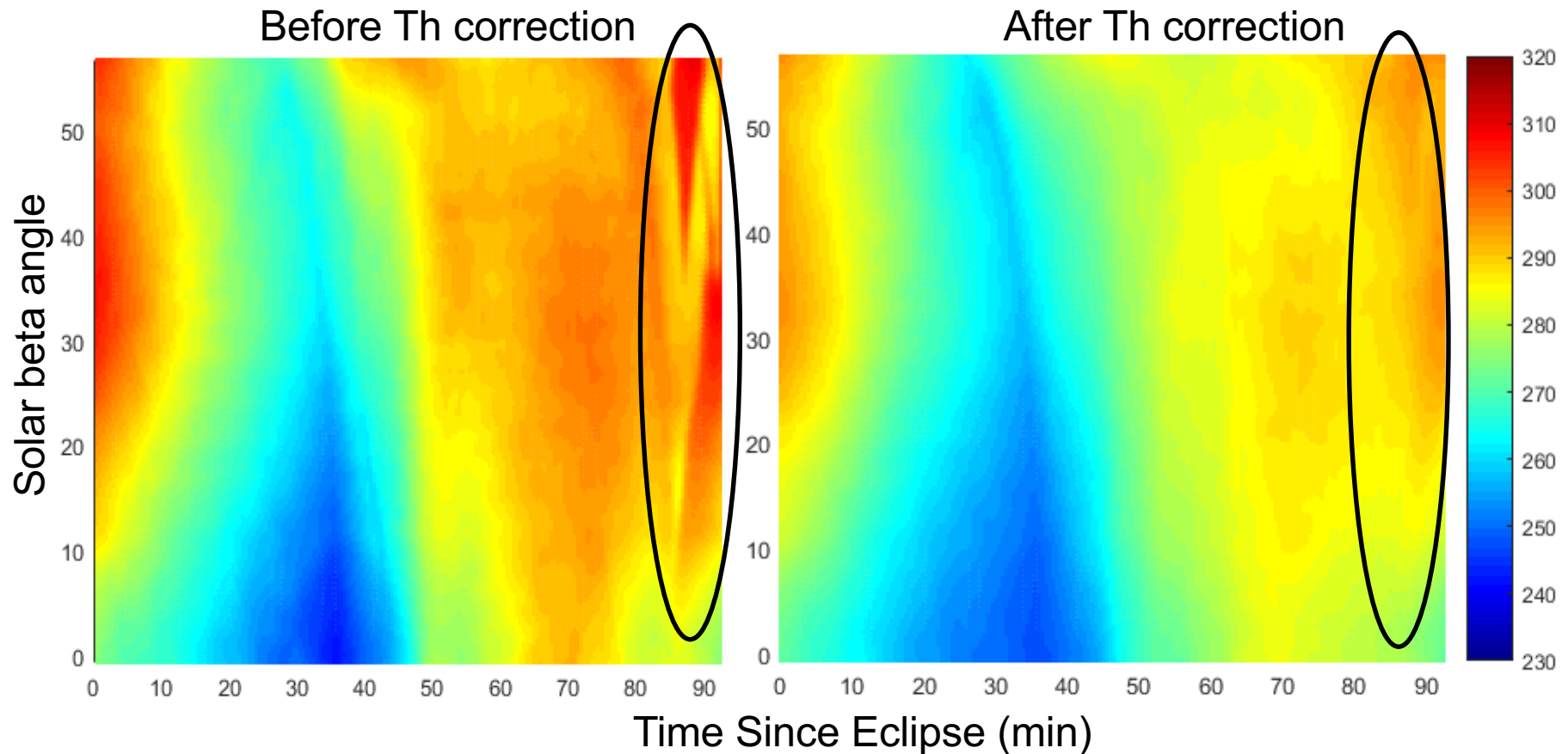
TMI Hot-Load Correction

Correction for solar intrusions into TMI hot-load implemented for V8 were different for pre- and post-boost



Main Reflector T_{phy} (2003-2013, yaw0)

After applying the hot load correction, T_{phy} was rederived

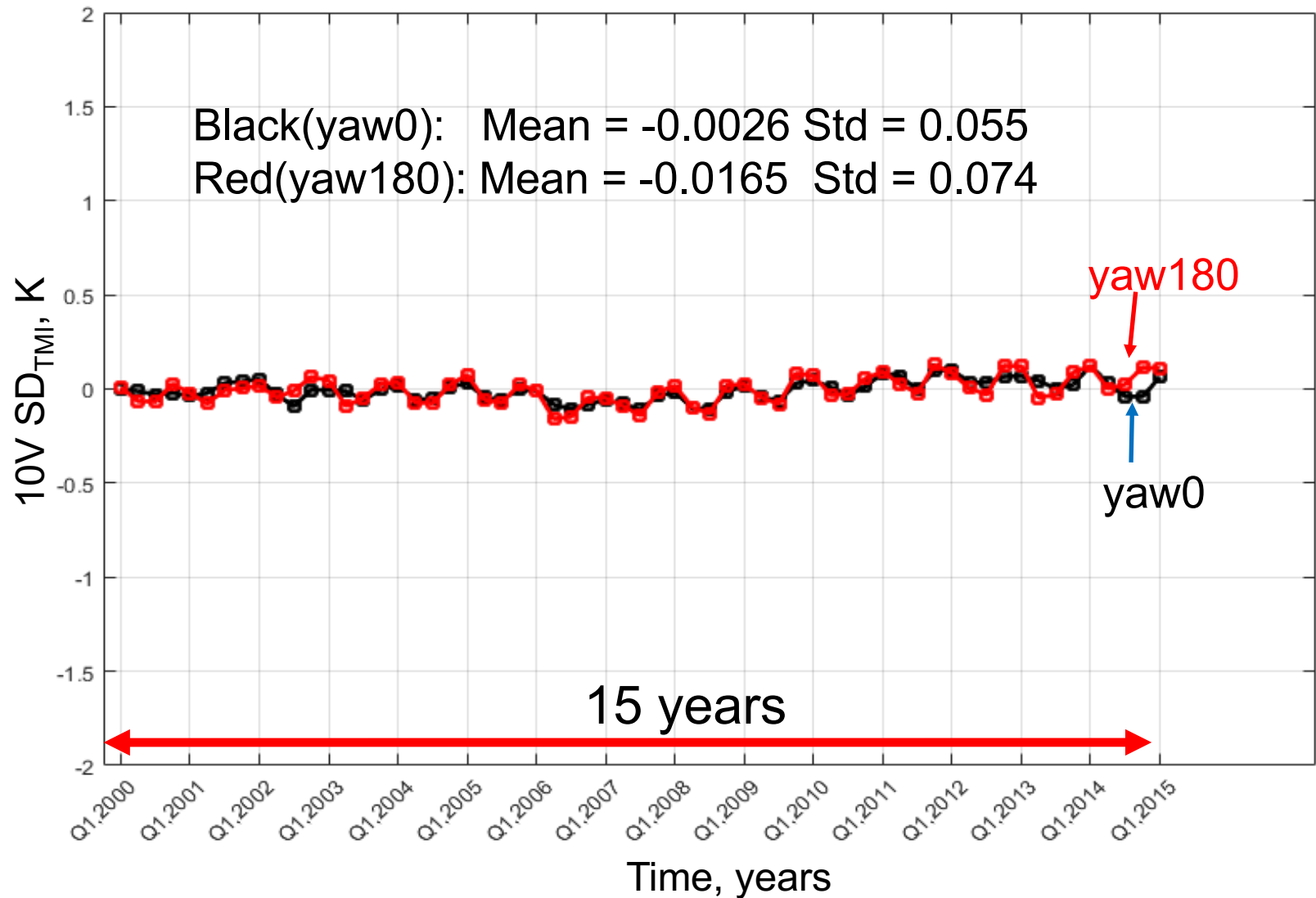


TMI Tb V8 Validation



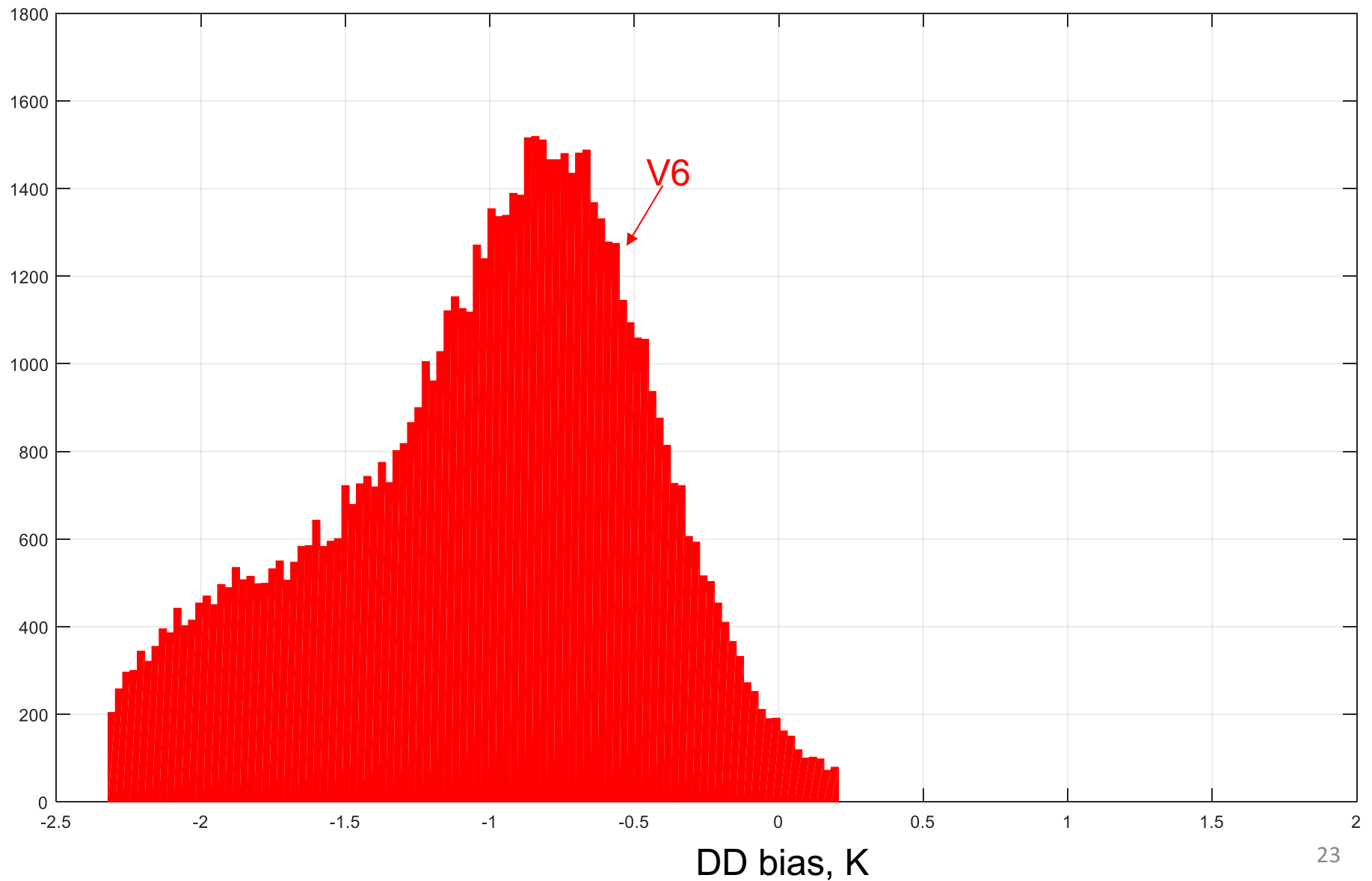
TMI V8 Tb Radiometric Stability

$10V SD_{TMI}$: 3-mo avg for 2000 – 2015



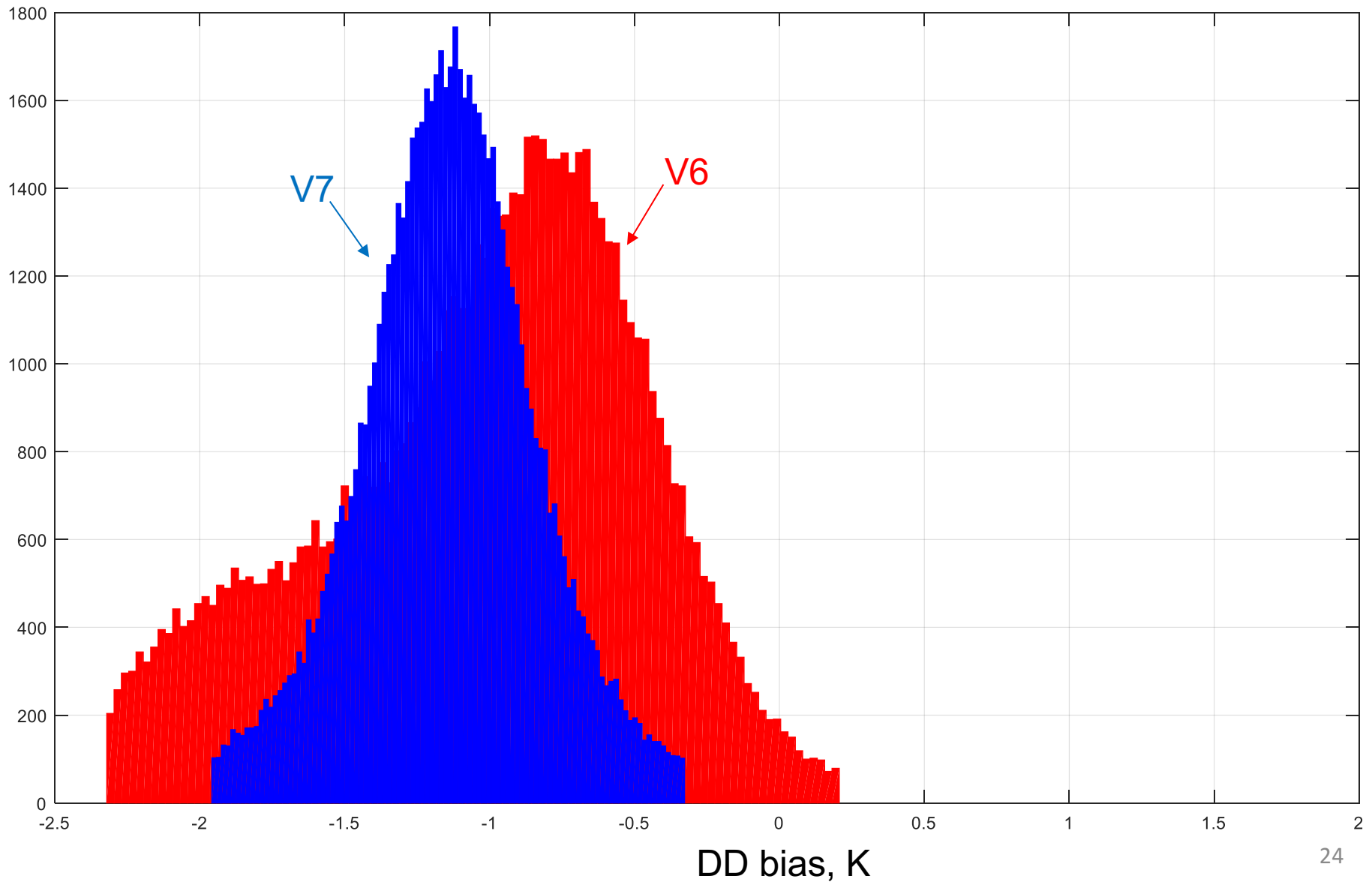
10V Chan DD Histograms (TMI & GMI)

- GMI (ITE101) , TMI(V06): Red,



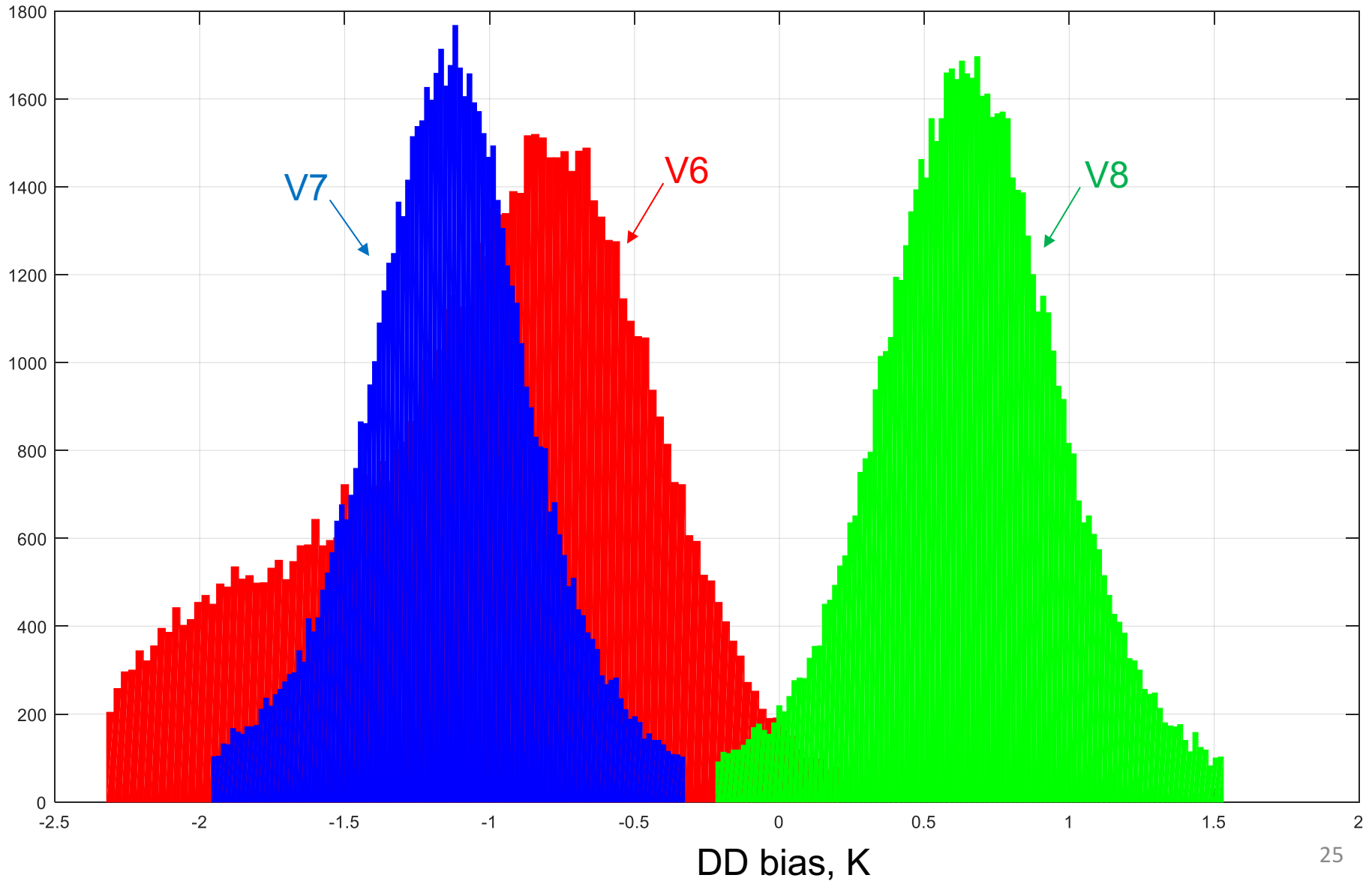
10V Chan DD Histograms (TMI & GMI)

- GMI (ITE101) , TMI(V06): Red, TMI(V07): Blue,



10V Chan DD Histograms (TMI & GMI)

- GMI (ITE101) , TMI(V06): Red, TMI(V07): Blue, TMI(V08):Green



Conclusions

- Development of legacy TMI version-8 Tb product is an extraordinary accomplishment of the XCAL team
- 1,000's hrs of collaborative effort have resulted in a TMI climate data record time, which will be used to calibrate the TRMM era constellation radiometers
- Provides a seamless transition of GPROF precipitation measurements from TRMM to GPM